Topic 7 Review Exercises (with answers)
WDTB Distance Learning Operations Course
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Part I. Sounding Parameter Matching (Student Guide pages 14-42)

The following thermodynamic and kinematic sounding parameters have ability in forecasting convective storm type. In certain situations, some of these parameters perform better than others**. Match** at least **ONE** relevant strength or limitation description to EACH parameter. A description may have more than one relevant parameter that matches it.

	Parameter (or value)		Strength or Limitation Description
A	7.5 m/s off the (0-6 km) mean wind to right or left of shear vector	**L**	Range of values from 20-100 m^2/s^2 indicate a preference for convective storms to develop low-level mesocyclones
B	Bulk Richardson Number (BRN)	**E,I,M,P**	Important to consider for MCS longevity
C	Hodograph length	**D, H, I**	Requires an estimate of storm motion
D	0-3 km Storm Relative Helicity	**H**	Increasing values from 1.0 to 3.0 and higher correspond to increasing probability of tornadic supercells
E	Positive Shear	**I**	When combined with sufficient S-R low-level winds (and CAPE), 8-10 m/s at 500 mb is a lower bound threshold for discriminating tornadic supercells
F	Steep sub-cloud temperature lapse rate	**A,G,M**	Can be used to estimate supercell motion
G	Hodograph shape	**J,Q,O**	Must consider the effects of lifted parcel choice, vertical distribution and model characteristics for effective application
H	Energy-Helicity Index (EHI)	**C,E,B**	Can provide estimate of rotation potential without an estimate of storm motion
I	S-R midlevel winds	**F**	Enhances dry microburst potential
J	CAPE	**H,C,D**	Indicates increasing tornadic supercell potential with increasing magnitude, but does not work as well with non-supercell tornado potential
K	Wet-Bulb Zero Height	**B**	Indicates supercells are likely when values are between 10 and 50
L	BRN shear	**E**	Not useful for anticyclonic-curved hodographs
M	Mean Wind Vector	**O, N**	A strong discriminator for significant tornadoes in supercells
N	Low-level (0-1 km) shear	**A**	Requires drawing mean shear vector on hodograph to estimate supercell motion

O	LCL height	**O**	The 1500m AGL upper bound threshold applies only to supercells with significant (F2 or greater) tornadoes
P	Low-level (0-2.5 km) shear	**J, Q**	Assumes no mixing with the surrounding environment, and ignores effects of freezing and water loading
Q	CIN	**K**	Only partially predicts severe hail potential because it doesn't consider updraft strength or particle trajectory
		D, B, L	Loses effectiveness in predicting storm type in extremely high (or low) CAPE situations
		C	Indicates potential for supercells if magnitude is > 15-20 m/s over SFC to 6 km layer (AGL).
		F	Not as important for forcing wet microbursts as it is for dry microbursts
		G	Requires a qualitative assessment of the hodograph
		M	Useful in forecasting ordinary cell motion
		D	Very good at assessing midlevel rotational potential in thunderstorms
		J	Provides estimate of updraft strength
		K	Values of 7000 to 10,500 ft AGL generally indicate a potential for large hail
		P	In RKW theory, requires additional assessment of cold pool strength to estimate MCS longevity
		M	Propagation effects cause storms to deviate from this vector
		O	Computations using mean 100 mb layer from the surface is the best method to use this parameter to estimate cloud base; related to amount of low-level relative humidity which can affect evaporation in downdraft of supercells
		E,J,M,P	A factor in multicell storm propagation
		C,D,E,I,L	Used as a good predictor for supercells but not tornadoes
		N	Most sensitive to vertical resolution in the models and AWIPS displays
		Q	Quantifies the amount of work required to lift a parcel through an environmental layer that is warmer than the parcel

Part II. Shear and Buoyancy Relationships (Student Guide pages 14-27)

1. Briefly explain why it is important to use both kinematic and thermodynamic parameters to assess storm type? Discuss some ways concepts covered in Topic 7 have changed your knowledge and/or techniques used in anticipating convective storm structure and potential evolution.

Answer: Severe convection is not the result of random or unpredictable processes. Research has shown that severe weather is related to development of both strong updrafts/downdrafts (which help determine event intensity), and the interaction of the updraft/downdraft with the environmental vertical shear (which strongly controls the degree to which storms become organized). A single parameter such as CAPE, shear or EHI can have a relatively high false alarm rate when assessed collectively. It is best to examine soundings individually and assess parameters on a case by case basis. Please review Section 3 of the Parameter's Web site.

2. Briefly describe the effects of midlevel dry air on storm intensity and evolution.

Answer: From observational studies and numerical simulations, the role of midlevel dry air has a dichotomous effect on storm systems. Dry midlevel air that is entrained into both storm updrafts and downdrafts will tend to decrease potential updraft buoyancy (and any associated mesocyclone development) but increase potential downdraft negative buoyancy (and associated damaging wind gust potential).

There also tends to be a relationship with mean wind and large scale forcing with downdraft energy. When the mean wind and large scale forcing are weak, the potential for strong downdrafts and resulting cold pools play a significant role in increasing storm intensity and longevity. By contrast, when mean wind and synoptic forcing are strong, severe surface winds can occur with relatively weak downdrafts and cold pools. See Objective 3 in Lesson 1 of the Student Guide for a discussion of the effects of dry air.

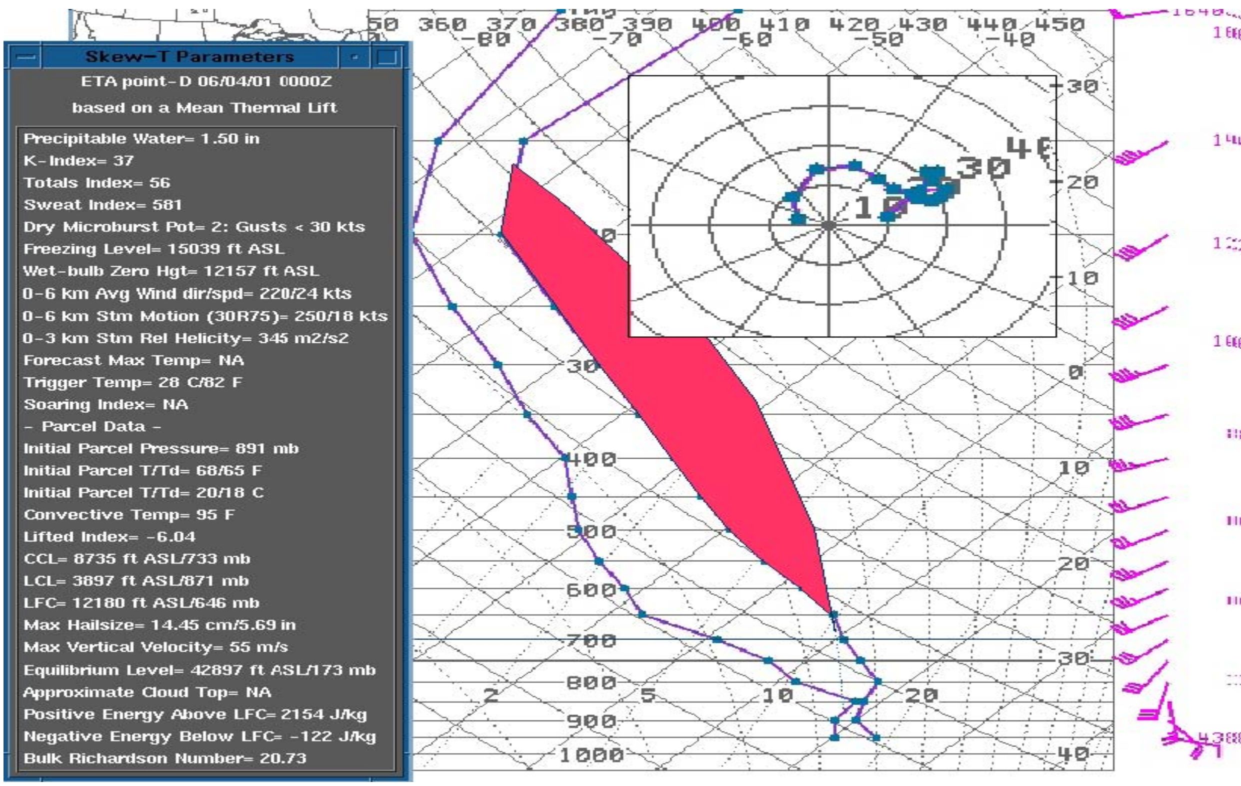
3. Choose the most accurate statement regarding the effects of midlevel dry air in thunderstorm environments characterized by large buoyancy. (Note: assume there is ample lifting to produce convection)

A) Dry air will tend to weaken thunderstorm downdrafts
B) Dry air will weaken the cold pool
C) DCAPE is a good indicator of downdraft intensity
D) If the mean wind is weak, severe surface winds are most likely if a strong cold pool develops

4. Choose two accurate statements regarding the effects of shear depth on convective storms.

A) Based on observations, the ambient shear in the lowest 1 to 2 km above the ground is strongest in both tornadic supercells and long-lasting multicell systems.
B) Observations indicate shear in the 0 to 6 km layer above the ground can effectively discriminate tornadic potential in supercells.
C) Increasing rear-to-front flow in the mid and upper levels is critical for maintenance of multicell storms.
D) Given sufficient instability, shear depth combined with storm motion can determine to a large degree the organizational mode of most storm types.

5. Yes or No. Splitting thunderstorms would be possible in the given environment (see sounding below). Please explain.



Yes. Despite zero SBCAPE, there is sufficient MUCAPE (see area in red) and strong enough deep layer-shear (> 40 kts). Also, hodograph indicated unidirectional winds in the inflow layer. Thus, splitting supercells are possible. Sounding shown was from 06/04/01 near ICT and in this case, a large supercell storm (which produced 2" hail) was the survivor of a split west of Wichita, KS. This case shows the importance of evaluating parcel characteristics for computations of CAPE and shear in the convective inflow layer. (Note: this was discussed on Day 1 of the teletraining and is explained on the [Parameters web site)](Parameters web site) .

Part III. Production and Detection of Severe Weather (Student Guide pages 43-192)

1. The initial intense precipitation core in an echo develops when the updraft reaches:
   A) a height of 20,000 ft or greater
   B) the 500 mb pressure level
   C) -10 deg C to -20 deg C layer
   D) a 50 dBZ core

2. The most useful technique for inferring an updraft location for pulse storm is to observe the location of:
   A) upper-level reflectivity core
   B) storm-top divergence
   C) low-level convergence
   D) highest VIL

3. What are the characteristics of a weakly sheared ordinary thunderstorm in terms of environment storm structure and evolution?

   A) Mean shear of < 20 kts, vertical (no tilt), and 30 min lifetime
   B) Mean shear of < 20 kts, sufficient CAPE, vertical (no tilt), and 30 min lifetime
   C) Mean shear of < 20 kts, large CAPE, 15-20 dBZ echoes above 0 deg C, 1 hr.
   D) Updraft/downdraft co-located, sufficient CAPE, and storms moving with mean wind

4. List at least 3 characteristics of dry microbursts environments.
   (From objective 8a) Any 3 of these will work.:

   1) Theta-E differences of greater than 25 to 30 deg K between the surface and a midlevel layer somewhere 3-6 km AGL containing the level of minimum theta-E.

   2) high LCLs ; also LCLs below freezing

   3) Deep subcloud layer (for evaporative cooling)

   4) Large (> 400) DCAPE values

   5) Reflectivities > 45 dBZ if lapse rates are < 8 deg K/km

   6) Cloud material above the melting layer

5. Describe the best ways to predict the motion of convective storms.

A) Ordinary cells

Use 0-6 km mean wind or 0-6 km density-weighted wind (if deeper storms are expected). For low-topped storms, use a shallower mean wind . A 2-4 km layer was a reasonable steering layer flow for Florida thunderstorms (Wilson and Megenhardt, 1997).

B) Supercells

Take 7.5 m/s off the (0-6 km) mean wind to right or left of mean shear vector. The shear vector should intersect the shear-orthogonal line at the 0-6 km mean wind. See Figure 7-49 on pg. 88 of the Student Guide. The 30R75 technique that is used in AWIPS skew-T displays was devised to only work for cyclonically rotating storms. It doesn't work for supercell storms that do not have deviant motion or for storms that are left-movers.

C) Multicells

Multicell motion is most complex of all storm types due to many mechanisms influencing their movement (shear-cold pool interactions, low-level convergence, system-relative flow, instability, and boundary interactions). A simplistic estimation of motion for multicell systems is given by the vector addition of the convective steering layer flow (Vcl) , which is typically the avg. wind from the LFC to the EL, and the propagation vector (Vprop). Corfidi et al. (1996) showed that the negative of the low-level jet (at 850 mb) can be a first approximation to Vprop. However, later observations have shown this method can fail, especially in situations where multicell systems are forward-propagating . An alternative technique is available to account for cold pool motion that occurs in the downshear direction (See Figures 7-87, 7-88 on pgs. 143-144).

6. Briefly describe the effects of shear on storm propagation.

(From Obj. 10) Vertical vorticity in convective updrafts results from the tilting of horizontal vorticity, which is produced by ambient vertical wind shear. The tilted vorticity centers in the updraft region form mid-level rotation and associated low pressure centers, which create rotating updrafts on the flanks. The separated rotating updrafts then begin to move off to the left or right of the mean wind depending on the shape of the hodograph.

7. Identify 4 reflectivity characteristics of supercell storms.

(From Obj. 14) There are 4 unique reflectivity characteristics of supercells:

1) low-level reflectivity notch on inflow side of storm, 2) hook echo, 3) WER, 4) BWER

Note: These are unique reflectivity characteristics (although some multicell structures may briefly display WERs/BWERs, they are likely supercells embedded in the overall multicell structure). However, not all supercells will display any or all of these radar traits. Often, a trailing appendage and/or mid-level overhang is all that shows up on reflectivity. Also, range limitations will distort/limit the appearance of these features.

Also, remember a WER and a BWER should be capped by high reflectivities (> 45 dBZ) with the top of the vault regions between 8 and 25 kft AGL. WERs and/or BWERs that are not capped by strong reflectivities imply weak or no updraft. In addition, the WER (and/or BWER) should be adjacent to the part of the low-level reflectivity core with the highest ref. gradients on the low-level storm inflow side (See Fig. 7-51).

8. What are the two critical ingredients for non-supercell tornadoes?

(From Obj. 8b) Tornadoes that form from the boundary layer need 1) sufficient low-level vertical vorticity, and 2) a strong enough updraft (See Fig. 7-32).

9. Describe the criteria for determining an operator-defined mesocyclone.

Based on definitions stated on pg. 95 of the Student Guide, a mesocyclone is a small-scale rotation closely associated with an updraft of a convective storm that meets or exceeds established criteria for shear, vertical extent, and persistence. For shear, we are evaluating the meso core diameter to be less than 5 nm so that it is indeed storm scale rotation. The diameter is defined as the distance between the maximum inbound and outbound velocities. Shear can be approximated by evaluating rotational velocity (shear/diameter) by this equation:

$$V_r = (|V_{in}| + |V_{out}|) / 2,$$

where Vin and Vout are the absolute values of the maximum inbound and outbound velocities in the observed range bins, respectively. Vertical continuity is important for confirming a deep circulation (10 kft is used as a minimum depth in algorithms, but operationally, 6 to 7 kft has been observed in mini or low-topped supercells). Persistence for at least a couple of volume scans ensures that the feature is for real.

10. Identify 3 characteristics of LP supercells.

(From Obj. 14 and Fig 7-59) Any 3 of these will work: 1) dominated by updrafts, 2) outflow deficient, 3) weak max reflectivities, 4) core consists of few large hailstones, 5) very high storm-relative anvil-level winds (> 30 m/s), 6) poor rainfall producers, 7) rarely a hook, and 8) relatively dry in boundary layer.

11. Identify 3 characteristics of classic supercells.

(From Obj. 14 and Fig. 7-60) Any 3 of these will work: 1) Produces a downdraft (RFD), 2) forms in moister environments, 3) low storm-relative anvil-layer winds (between 18-30 m/s), 4) cyclic tornado producers (also long-trackers), 5) threat of severe winds, hail and tornadoes, 6) heavy rain and hail core NW of updraft region, 7) more likely to contain a low-level meso on radar, 8) often displays a hook echo on radar reflectivity.

12. Identify 3 characteristics of high precipitation supercells.

(From Obj. 14 and Fig. 7-61) Any 3 of these will work: 1) most common of all three supercell types, 2) highly efficient precipitation producers, 3) often produces strong downdrafts and outflows, 4) makes a large, fat hook echo, 5) strongest ref. core behind and to the right of meso path, 6) typically evolves to bow echoes , 7) likely to contain a low-level meso, 8) difficult to obtain visuals on any associated tornadoes, 9) High BL moisture , 10) weaker anvil-level SR-flow (< 18 m/s), 11) supports all svr wax threats (hail, tornadoes, winds, flash flooding)

13. What are the primary distinguishing characteristics of mini supercells?

They are low-topped (20-30 kft AGL). They typically have more diminutive dimensions horizontally and vertically. Typically, rotational velocities in associated mini mesos supporting tornadic storms are lower (often < 30 kts) than more common Great Plains' supercells . Giant hail is not as common due to smaller, weaker updrafts. See pg. 106 in the student guide.

14. What are three major signatures for determining large hail in supercells?

(From Obj. 15) Any 3 of these are correct:
1) sustained updraft with large WER, 2) BWER, 3) increased deviant motion relative to steering-layer flow, 4) strong SR-Flow (through upper-levels), 5) deep, strong mesocyclone, 6) large buoyancy (via CAPE or lapse rates) in mid to upper levels, 7) broad updraft, 8) elevated high reflectivities, 9) seasonably high VILs or VIL densities, 10) Three-Body scatter spike, 11) Storm-top divergence.

15. What are the criteria for determining an operator-defined tornado vortex signature?

(From Obj. 15) A TVS is a gate-to-gate, azimuthal shear possibly associated with tornadic rotation that meets or exceeds established criteria for shear, vertical extent and persistence. Shear is quantified in radar data as the velocity difference between two adjacent gates (see Fig. 7-69). Vertical extent (for most events at least 1500 m) should be seen in a TVS so that there is confirmation of an updraft present in the circulation. Persistence for at last 5 minutes reduces the chance for a non-meteorological signature.

16. Describe 2 major meteorological factors that contribute to flash flooding in supercells and multicells.

(From Objective 15d and Objective 19) Heavy rainfall depends on: 1) instantaneous rainfall rate and 2) expected duration. The instantaneous rainfall rate is a function of precipitation efficiency and upward moisture flux. Heavy rainfall duration is largely determined by storm motion.

17. Which type of MCS will typically move faster, trailing stratiform, leading stratiform, or parallel stratiform?

(From Obj. 16) The answer is trailing stratiform. Although MCSs develop a number of ways, all mature systems eventually develop convective regions and stratiform precipitation regions. The type of MCS is determined to a large extent by the environmental conditions in which it develops and the strength of the system cold pool. Parker and Johnson (2000) studied MCS types and determined the distribution of hydrometers and stratiform precipitation shapes were largely a result of mean storm-relative winds. The speed and direction of the environmental mid and upper-level winds relative to the system's motion affects the resulting evolution of the MCS. Thus, storm (or system) - relative wind fields are critical to the evolution and movement of multicell systems. According to their studies, Parker and Johnson found MCSs evolve into three major archetypes: 1) trailing stratiform, 2) leading stratiform, and 3) parallel stratiform. The main distinction arises from storm-relative flow fields. The leading stratiform precipitation MCS archetypes, which are typically slower-moving than trailing stratiform systems, were characterized by stronger mid and upper-level storm-relative flow (often described as rear-to-front flow) than any of the other types (see Figure 7-81). The trailing stratiform MCS types have a sloped front-to rear flow produced by stronger system-relative flow in low-levels and subsequent stronger low-level convergence along the leading edge. They move the fastest and have the tightest reflectivity gradient along the leading edge.

18. Factors affecting multicell storm propagation include ________________ (please identify at least 3).

(From Obj. 16) Multiple mechanisms exist for influencing the movement of multicells. These include: 1) shear-cold pool interactions 2) storm or system-relative flow (and subsequent low-level convergence), 3) instability gradients, and 4) boundary interactions. (Note: Deep layer winds also influence multicell movement)

19. Describe the evolution of bookend vortices in bow echoes.

(From Obj. 18) From numerical simulations and observations, when cyclonic and anticyclonic line-end vortices are generated within a squall line system during the initial 3-4 hrs., the impact of mid-level convergence in the presence of Coriolis forcing acts in time to weaken the southern anticyclonic line-end vortex, but strengthen the northern cyclonic "bookend" vortex. This strengthening of the cyclonic "bookend" vortex over time is what produces the symmetric-to-asymmetric system evolution that characterizes most long-lived MCSs . Persistent Front-to-rear (FTR) flow also contributes to the asymmetric structure.

20. Describe the inverse relationship between CAPE and shear in observed environments of squall lines and bow echoes.

(From Obj. 18) The answer is the intensity and longevity of squall lines and bow echoes occur within a wide range of environmental conditions and shear/buoyancy parameters. For stronger synoptic forcing, deep layer shear is stronger and CAPE is usually smaller. In weaker synoptic forcing, higher CAPE and DCAPE are necessary to maintain the strong winds at the surface. Thus, in weak flow situations, strong downdrafts (from the big CAPE, steep midlevel lapse rates, midlevel dry air) and associated cold pools are critical for maintaining the severe surface winds.

21. According to numerical simulations, which type of Rear-Inflow Jets (descending or non-descending) tend to live longer?

(From Obj. 17) the answer is non-descending RIJs. According to simulations by Weisman (1992), a descending RIJ occurs when the vorticity generated below the front-to-rear sloped updraft is weaker than the opposite sign vorticity generated by the cold pool. The vorticity imbalance helps to force the RIJ downward toward the ground before it can reach the leading edge of the gust front with all its momentum. This usually occurs with weaker shear and/or less CAPE. However, if CAPE and/or shear is increased, the vorticity underneath the rearward expanding anvil becomes much larger (due to increased buoyancy), and the counter rotating vorticity along the back of the cold dome does not increase as much. This situation leads to increased buoyancy-induced vorticity under the anvil matching the cold dome vorticity producing a more horizontally oriented RIJ (see Fig. 7-96, 7-97). This non-descending RIJ moves toward the leading edge of the cold pool with a horizontal vorticity structure that keeps the cold pool from spreading past the gust front. Thus, the strength of the gust front vorticity lessens and becomes more balanced with the environment and the squall line retains an upright updraft. These types of squall

line structures tended to live longer than those with a descending RIJ.

22. Identify 3 signatures for high winds in multicells.

(**From Obj. 19) In the absence of moderate to strong shear, multicells will typically possess a linear structure (see Fig.'s 7-113, 7-114, 7-115).**

Any of these 3 signatures which indicate a high wind potential are correct:

1) Strong reflectivity gradients along the leading edge (indicate a sharp updraft-downdraft interface)

2) MARC signature (indicates a deep convergence zone)

3) Bow echo

4) WER/BWER

5) Gust front well-matched to the system speed (indicates a persistent, strong updraft)

6) Mature stage of system

23. Identify the principal signature related to movement that produces heavy (potentially flash-flooding) rain.

(From Obj. 19) Back-building, or training of echoes in the multicell structure. This movement can be predicted by evaluating the propagation vector of the multicell cluster. If it points opposite to the cloud-bearing vector, look for enhanced heavy rain (and potential flash flooding). Also, low- level flow parallel to the upper-level flow can produce heavy rain if deep moisture profiles are present.